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THE GLACIAL CONGLOMERATE IN THE TABLE MOUNTAIN SERIES NEAR CLANWILLIAM.

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(Read September 28, 1904.)

Four years ago I laid before the Society some evidence of glacial action in the Table Mountain series from the Pakhuis Pass near Clanwilliam. I have lately had an opportunity of searching the western flank of the Cederberg range for more outcrops of the conglomerate, and I traced the rock in question over an area fifteen miles in length and about seven in width. The total length of the lines along which the conglomerate has been followed, including the frequent intervals between outcrops, where the rock is concealed beneath the soil and fallen *débris*, is twenty-three miles. Even where the rock itself is not visible the form of the ground indicates its presence.

A visit to the Pakhuis Pass was not rewarded by the finding of any additional exposures to those described in the earlier communication.

From Botha's Berg the clearly-marked feature on the mountain slope, caused by the presence of the shale band, at the base of which the conglomerate occurs, was followed west-north-west through Rheebok's Vley, Vark Fontein Extension, Klein Vley Extension, Klein Vley, Zand Kraal Extension, to Lange Kloof, on the

Olifant's river, where the horizon is traversed by that river. There are two places along this line of country where the conglomerate can be well seen. One of these is on Klein Vley, in some dongas cut by storm-water from Mount Synnott. At the lower end of the dongas, near the Vark Fontein road, the ordinary, rather coarse, sandstones of the Table Mountain series, containing a few white quartz pebbles, are seen, but the actual junction with the overlying conglomerate is not exposed. The beds dip at an angle of about 10° to the north-east. In the dongas a vertical thickness of some forty feet of conglomerate is laid bare. The rock is much weathered, and is yellowish-red in colour. The matrix is a sandy mudstone without lamination planes. The majority of the enclosed pebbles are micaceous clayey sandstones, often thinly laminated. This rock resembles the sandstones of the Ibiquas beds more closely than any other known to me. Pebbles of quartz and quartzite are fairly abundant in this locality, but no fragments of granite or other igneous rock were met with. The pebbles range up to eight inches in length. Only a few of them were found to be striated, and these were of small size. The upper part of the conglomerate and the shale above are hidden by the *débris* from the Mount Synnott escarpment.

On the farm Lange Kloof, just below the boundary between it and Zand Kraal Extension, a short kloof has been cut back from the Lange Kloof river along the shale band, and there are several outcrops of the conglomerate in the upper part of the kloof, while yellowish-red, thinly-laminated sandy shales are seen to lie above the conglomerate. The sandstones below are similar to those at Klein Vley Extension, and the conglomerates at the two places are very much alike. The conglomerate at Lange Kloof is eighty feet thick, and over two hundred feet of shales lie between it and the overlying sandstone, which is a coarse, false bedded rock with scattered quartz pebbles. Several small scratched stones were found in the conglomerate here.

Near the boundary between Klein Vley and Groot Patrys Vley there is a conical hill, oval in plan, above the left bank of the Kliphuis river. The base of the hill consists of the sandstones below the shale band, which forms an elliptical area, and above the shale band there is an outlier of the upper sandstones. There are many outcrops of conglomerate and shale round this hill, and the passage from the unbedded mudstone with pebbles, about one hundred feet thick, through twenty feet of laminated shale with pebbles, to the thinly-laminated shale without pebbles, of which there are some two hundred feet, can be found without much

difficulty in the numerous small ravines on the steep slopes of the hill. Pebbles up to fifteen inches in length are embedded in the mudstone at the bottom of the outlier, and striated stones can be obtained. Most of the pebbles are water-worn and well-rounded, but striations occur on many of those as well as on the subangular pieces of rock. The lowest portion of the conglomerate here is red, and the colour seems to be an original feature; the upper part, and the shales above, are yellowish at the surface and greenish within. The usual colour of the shales in the Table Mountain series is red, but both the shales and the conglomerate of Pakhuis are greenish when unaffected by the weather.

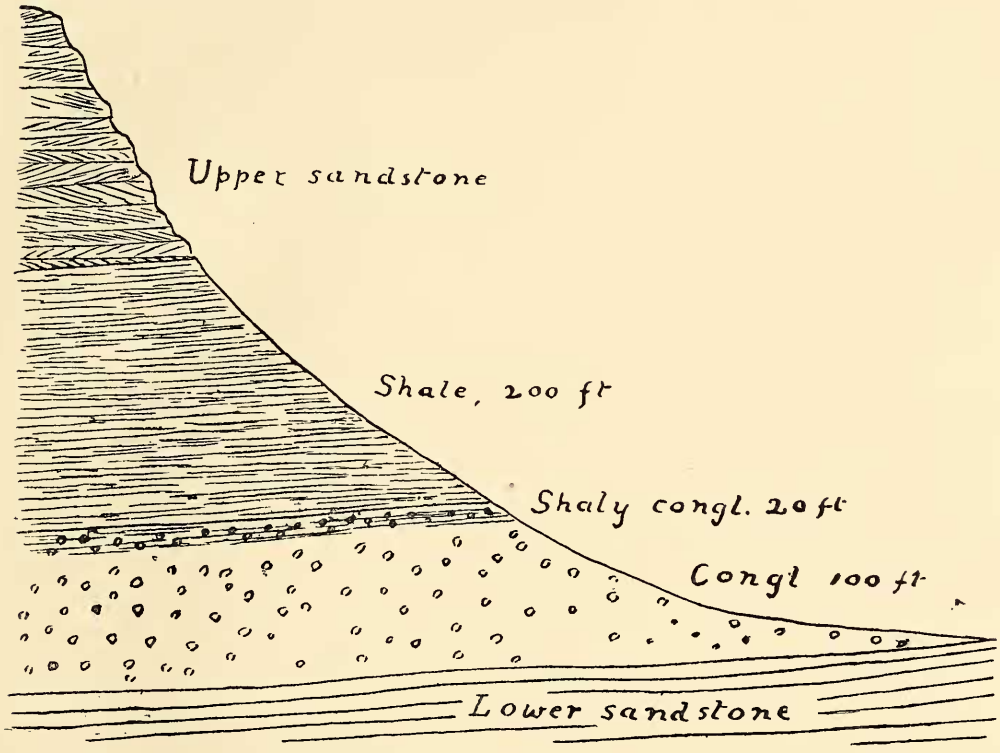

Fig. 1.—Section through south-west side of outlier on boundary of Klein Vley and Groot Portrys Vley.

South-east of the outlier on Klein Vley the sandstones below the shale band form a great area on the western slope of the Cederbergen; between Lange Kloof and the path to Krakadouw these lower sandstones abut against beds belonging to a higher horizon along the Augsburg fault. On the south-west side of the Jan Dissel's river the shale band crops out again, but it is here on the downthrow side of the Augsburg fault. I followed it across the watershed between the Jan Dissel's and Keurbosch Kraal river for a distance of over five miles along the outcrop, and it can be seen to extend far to the south, though it becomes thinner in that direction. The total thick-

ness of the shale band in this neighbourhood is three hundred feet, of which the lowest hundred feet are of reddish-yellow weathering conglomerate. In the two kloofs cut along this horizon, which lead north to the Jan Dissel's river and south to the Keurbosch Kraal river respectively, there are many very good exposures of all parts of the conglomeratic rock, including the passage beds into the underlying sandstones on the one hand and the overlying shales on the other. The coarse sandstone below becomes more and more argillaceous towards its upper limit, and the included pebbles increase in numbers and variety, till within a vertical distance of twenty feet from the normal type of sandstone the rock assumes the character of the Pakhuis conglomerate. The passage upwards into the shales without pebbles comes about by the gradual decrease in numbers of the pebbles and the greater frequency of lamination planes in the sandy mudstone towards the top of the conglomerate. Pebbles of quartz, quartzites of three kinds, sandstones, felspathic grits, diabase, amygdaloidal rocks of the Zeekoe Baard type, and granite were noticed in these exposures, and several of them are flattened on one or more sides, and well striated. A dozen pebbles, from two to five inches in length, showing characteristic glacial striations, were found in this locality during the three hours I spent on the five miles of country between the two rivers mentioned above. Some very good exposures of the conglomerate, thirty feet in height and many yards long, can be seen on the banks of the stream entering the Keurbosch Kraal river. The pebbles are scattered quite irregularly through the sandy mudstone, which has a purplish colour; they are hardly abundant enough to give the rock the appearance of a conglomerate on a casual inspection, and areas of many square feet show no pebbles.

In the former communication on this subject it was pointed out that though the evidence given therein was sufficient to justify the belief that the glacial conglomerate really belonged to the Table Mountain series, and was not an outlier of the Dwyka conglomerate to which it had some resemblance, further facts to prove its stratigraphical position were desirable. These later observations place the conclusion then arrived at beyond dispute. In each of the localities described above the position of the conglomerate is the same, viz., at the base of the shale band, and in each place, so far as one can judge from the not very satisfactory sections, the conglomerate forms about a third of the thickness of the shale band. The gradual passage from the lower sandstones into the conglomerate on Bosch Kloof is clear evidence as to the relationship of the two rocks, and the passage upwards into the shale without pebbles has

been ascertained on the Pakhuis Pass, at Bosch Kloof, and on Klein Vley, while a considerable thickness of the upper sandstones overlies the shale band at all the localities. The reappearance of the conglomerate on the downthrow side of the Augsburg fault most decidedly confirms the conclusion that the rock belongs to the Table Mountain series.

Though there is a certain resemblance between the Pakhuis and Dwyka conglomerates there are important points of difference. The Dwyka conglomerate is remarkable amongst other things for being so constant in colour and appearance throughout a great region, with one general distinction between the northern and southern outcrops, due to the greater amount of alteration induced by earth-movements in the south. Now the Pakhuis conglomerate varies considerably even within the short range of twenty-three miles through which it has been traced. The red rock at the base of the Klein Vley outlier has no counterpart in the Dwyka conglomerate.

The variety of rocks occurring as boulders and pebbles in the Pakhuis conglomerate is considerably less than in the Dwyka, and quartz, quartzites and sandstones are more abundant in proportion to rocks of igneous origin in the former than in the latter. There is one peculiarity, in addition to the glacial striations, common to the boulders of the two conglomerates: many of them are traversed by several parallel planes along which they break easily,* and those planes are independent of the original structural planes of the rocks from which the boulders were derived. In each of the outcrops of the Pakhuis conglomerate these jointed pebbles can be found, and it was noticeable that the elongated pebbles were more frequently

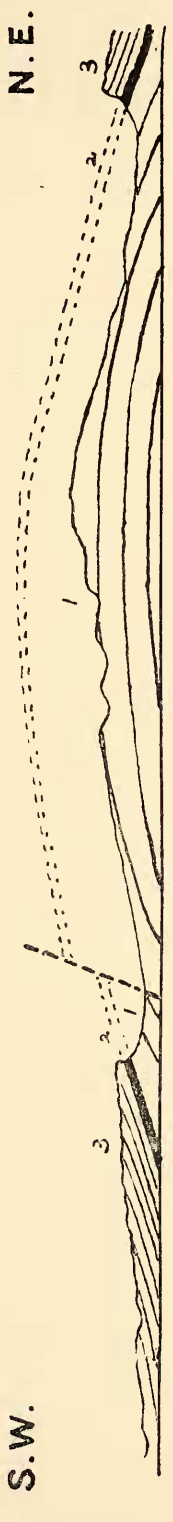

Fig. 2.—Section across the Cederberg Anticline and the Augsburg Fault.

3. Upper sandstones } Table Mountain Series.
2. Shale band
1. Lower sandstones

Vertical scale, $\frac{1}{10}$ in. to 650 ft. Horizontal distance, 13 miles.

* See Schwarz, Trans. Phil. Soc., vol. xiv., p. 385, 1903. A figure of a jointed boulder from the Dwyka conglomerate of Prieska is given there.

jointed than those of a roughly spherical form, and that the joints traversed the pebbles approximately at right angles to their longer axes in whatever positions the pebbles lay in the matrix.

In order to get some idea as to the conditions that prevailed during the formation of the Pakhuis conglomerate we must briefly recall the nature and distribution of the group of which it forms quite a subordinate part. The Table Mountain series consists chiefly of rather coarse sandstone, usually strongly false-bedded, and it contains many isolated water-worn pebbles of quartz distributed irregularly through the greater part of the sandstone. Occasionally, the pebbles occur together in layers one pebble thick; much more rarely they are sufficiently abundant to warrant the rock being called a conglomerate; in such cases, as at Pikenier's Kloof, Baboon Point, and a few other places in the Western districts, slates, sandstones, granite, and jasper are met with in the form of pebbles in addition to the usual vein-quartz. Argillaceous beds form but a very small proportion of the whole series: there is one group of them near the top, the shale-band to which the Pakhuis conglomerate belongs, and which has been followed through a distance of some 300 miles round the Colony, and there are irregularly-developed bands of red shale near the base of the formation. The whole thickness of the series is about 5,000 feet, of which probably not more than a twelfth is noticeably argillaceous. Current-bedding and ripple-marks can generally be found throughout the group, and sun-cracked surfaces have been seen in some of the red shaly beds near the base, so it is evident that the formation was deposited in shallow water, and at places parts of the area were laid bare for a short time before fresh sediment buried the dry surface of previously deposited mud. Although the whole region occupied by the formation between the Bokkeveld Mountain in Calvinia and the Umtamvuna river, where it passes into Natal, has not been carefully examined, the above description probably applies everywhere within those limits. The area in which the formation can be seen, or can be legitimately assumed to exist under the present surface, is at least 80,000 square miles in extent. No organic remains, except some obscure tracks or worm-castings, have as yet been found in the series; and the rocks are now sufficiently well known to allow one to hold that there are no important bands containing marine fossils. These facts most certainly negative the idea that the Table Mountain series was laid down under the sea, and it is difficult to reconcile the supposition of a lacustrine origin with the wide distribution of so much coarse sand, for in the tranquil water of a lake the coarse material brought into it by rivers is not spread over the whole area

but is dropped near the mouths of the streams. It is probable that the series was deposited by a river or several rivers running over a slowly subsiding area. On this supposition alone we get over the difficulty of the preponderance of coarse sediment, its great thickness, the occasional layers of pebbles, and the general absence of the fine-grained material which must have been produced by the denudation of the ancient land from which all the sand came. The fine mud must have been carried away and deposited beyond the area we have access to. As to the sources of the deposits it is unsafe to speculate, but there are good grounds for the belief that the northern part of Cape Colony was a contributor.

It is a well-known fact that great thicknesses of gravels, sands, and fine dust accumulate in desert regions, but the Table Mountain series does not agree in many points with desert formations. To take one important point, there are no deposits of soluble salts, such as gypsum and rock salt, within the group, nor have any pseudomorphs or casts of crystals of these substances been found in it. The presence of such deposits is characteristic of deserts, and their formation on a greater or smaller scale, dependent on the extent to which drainage facilities are wanting, is one of the necessary results of the conditions which give rise to desert regions.

Though fluviatile conditions will account for the bulk of the formation, the wide distribution of the shale band averaging two hundred feet in thickness in the upper part of the series points to a change of circumstances of considerable duration; an increased rate of depression of the area, by which it was removed from the limits of deposition of coarse material, and converted into a lake, may have brought about this change. It was in this lake that the mudstone forming the matrix of the Pakhuis conglomerate was deposited, and into it were dropped by floating ice the finely-striated boulders shaped by glacial action. From the absence of angular fragments freshly derived from the parent rock mass, we may suppose that the boulders were carried to the places where they are now found from a considerable distance; they were probably derived not from the immediate shores of the lake but from the country behind, by the combined agencies of glaciers, streams, and floating ice. The area over which the glacial conglomerate has been observed—less than one hundred square miles are included within the lines connecting the outcrops furthest removed from each other—is so minute compared with the whole extent of the formation, that it is as yet impossible to know how far the glacial conditions affected the whole area, but it is to be expected that the conglomerate, or at least

isolated glaciated pebbles are to be found far outside their range as known at present.

The striated stones have only been found in the lower hundred and twenty feet of the shale band, and below their upper limit the mudstone becomes bedded, and finally a thinly-laminated shale. Above the shale band the uppermost thousand feet or so of the formation seem to differ in no way from the sandstones below the shale band, so the fluviatile conditions returned and were maintained for a long period before the sea encroached upon the area and the Bokkeveld beds with their marine fossils began to be laid down.